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AUTHORITY
OSRD list no. 3 dtd 2-11 Jan 1946; OTS index dtd Jun 1947

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NATIONAL DEFENSE RESEARCH COMMITTEE
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OFFICE OF SCIENTIFIC RESEARCH AND DEVELOPMENT

"ALUMINUM SOAPS FOR THICKENING GASOLINE"

by
G. H. McIntyre, Director of Research
and S. B. Elliott, Chemist
Ferro Drier and Chemical Company

062344 01263

Report OSRD No. 3772
Copy No. 35
Date: June 13, 1944

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Division 11
NATIONAL DEFENSE RESEARCH COMMITTEE
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OFFICE OF SCIENTIFIC RESEARCH AND DEVELOPMENT

"ALUMINUM SOAPS FOR THICKENING GASOLINE"

Service Directives CWS-10, 21

Endorsement (1) From E. P. Stevenson, Chief, Division 11, to Dr. Irvin Stewart, Executive Secretary of the National Defense Research Committee.

Forwarding report and noting:

> "This report presents a broad survey of all the variables involved in the manufacture of Napalm thickening agent, including control of raw materials, the precipitation process, drying and packaging."

This is a final report on Contract 11-416, OEMsr-882 with Ferro Drier and Chemical Company.

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DIVISION 11.

National Defense Research Committee.

of the

Office of Scientific Research and Development

Report on "Aluminum Soaps for Thickening Gasoline

by

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Report O.S. R. D. No. OEMsr-882.

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INTRODUCTION

The research on Napalm conducted by Ferro Drier and Chemical Co. has covered the whole manufacturing process but has concentrated on certain phases of production. Though research on the various manufacturing operations was not conducted sequentially, nevertheless an examination of conclusions is most informative when the operational sequence is used as a guide. For this reason the report follows this outline:

I. Raw Materials Used.

1. Aluminum Sulfate
2. Red Oil

II. Preparation of the Sodium Soap.

1. Acid Ratios
2. Soap Concentration
3. Plant Control of the Sodium Soap

III. Precipitation of the Napalm

1. Required Type of Agitation
2. Degree of Washing Required
3. Factors Influencing Oxidation of the Napalm.

IV. Drying of the Napalm.

1. Proper Oven Conditions.

V. Packaging of the Napalm.

1. Moisture Sorption.

VI. Application of Napalm Gel.

1. Combustion of Gel.

VII. Unmodified Naphthenates as Napalm Substitutes.

ABSTRACT OF REPORT

I. Raw Materials Used.

1. Aluminum Sulfate. It was found desirable to keep iron and manganese sulfate at very low concentrations in aluminum sulfate to be used for Napalm manufacture but the use of sodium ferrocyanide to fix the iron in a Napalm insoluble complex is of great assistance if high purity aluminum sulfate cannot be procured.

2. Distilled Red Oils having titres of from 5° to about 15° were determined to be quite satisfactory for Napalm manufacture.

II. Preparation of the Sodium Soap.

1. A 50 coco, 25 oleic, 25 naphthenic acid formulation appeared to be most satisfactory for Napalm manufacture. The absence of oleic acid caused poor adhesion of the gel and high naphthenic acid caused undesirable sintering of the soap during manufacture.

2. A 12% sodium soap was found most desirable for the precipitation of Napalm.

3. Routine titrations can be used to determine the concentration of sodium soap and the combined - uncombined NaOH ratio in the sodium soap so as to closely control the Napalm.

III. Precipitation of Napalm.

1. Propeller type agitation can be used very successfully in the preparation of Napalm if precipitation conditions are adjusted correctly.

2. An initial separation of mother liquor after precipitation of the Napalm followed by an hour soaking in a 2% solution of aluminum sulfate produced Napalm as satisfactory as material which had been very thoroughly washed with tap water.

3. Several factors have been found to affect the length of the induction period of Napalm. Thus:

a. A pulp of high pH had a considerably shorter induction period than one of low pH.
b. A rise in temperature from 160° to 195° F. reduced the induction period to 21 - 25% of that found at the lower temperature.
c. The use of 0.1% α - naphthol in Napalm contributed excellent protection against aerial oxidation if oxidation catalysts such as iron soaps were present in small amounts.

d. Iron in a Napalm soluble form, as for example an iron soap, was very much more active as an oxidation catalyst than insoluble forms such as the hydrate.

IV. Drying of the Napalm.

1. Drying experiments indicated a Napalm dryer would be satisfactory if the air stream had a linear velocity of approximately 525 ft/min. and a temperature of 160° F. A cake depth of 1.5 in. was satisfactory.

V. Packaging of the Napalm.

1. Packaging of Napalm should be as rapid as possible in order to avoid excessive moisture pickup.

VI. Application of Napalm gel.

1. The addition of magnesium or B powder, Thermite, or Thermite and magnesium powder to B Napalm - gasoline gels did not improve combustability or flame temperature. Combustion of the metal was incomplete and occurred only when the gel had almost ceased burning.

VII. Unmodified Naphthenates as Napalm Substitutes.

Unmodified aluminum naphthenates were prepared and examined to determine whether they showed any advantages over Napalm as gasoline gelling materials. Though certain naphthenates appeared as satisfactory as Napalm there were no clear cut advantages apparent.

I. Raw Materials Used.

1. Aluminum Sulfate.

Early in the Napalm program it appeared doubtful whether aluminum sulfate could be obtained which was sufficiently low in iron to be satisfactory. It was considered, and later corroborated, that the fixing of the iron as a compound insoluble in Napalm would greatly diminish its activity as an oxidation catalyst. The addition to the aluminum sulfate solution of sufficient sodium ferrocyanide to fix the iron present and leave a 100% excess was found to stabilize the Napalm to aerial oxidation on drying and during subsequent storage. The Prussian and Turnbull Blues formed fixed the iron (as high as 0.25% was used) very well in acid solution and any subsequent decomposition in the alkaline sodium soap produced relatively inactive hydrate.

2. Red Oil.

Throughout a part of the research program 8 - 10° titre distilled Red Oil was in free supply and was used to produce satisfactory Napalm. Commercial production was then changed to a 10 - 12° titre product. To determine the effect of such a change a 10 - 12° titre Red Oil was chilled and separated into a fraction liquid at 5° C. and another fraction solid at 5° C. These were incorporated in representative 50 - 25 - 25 Napalm formulas and the following results secured:

Red Oil Fraction	Consistency 150° 24 hr.	Consistency R. T. 48 hr.
Liquid 5°	600	925
Solid 5°	640	950

From this it is apparent that moderate changes in the titre of the red oil used does not affect the consistency of the Napalm though the particle size of the precipitate does become smaller as the titre rises.

II. Preparation of the Sodium Soap.

1. Acid Ratios.

The most commonly used Napalm formula contained 50% coconut fatty acids, 25% naphthenic acids, and 25% oleic acid. Keeping all precipitation conditions the same but reducing the oleic and coco acid content and raising the naphthenic acid content was found to produce soaps which sintered much more readily than regular Napalm.

Complete sintering seemed to develop the maximum gasoline solvation and setting time. Whether it was composition, temperature, or compression which brought about the collapse of particle voids, the solvation and setting time was greatly extended as compared to the type readily permeated by solvents.

The following table indicates the change in properties brought about by removing oleic acid from the formulation:

Coco %	70	75	65
Oleic %	--	--	--
Naph %	30	25	35
Caustic	26.5	26.5	26.5
48 hr.	475	515	495
7 day	560	565	505
24 hr. @ 150°	505	535	495
Set	13.5 min	6.0 min	14.3 min.
Comments	Poor Adhesion	Poor Adhesion	Poor Adhesion

2. Sodium Soap Concentration.

There appears to be a definite disadvantage in operating at very low sodium soap concentrations. The following table indicates the change in the strength of gels prepared from the finished Napalms:

Conc. Sodium Soap.	Consistency 24 hrs. @ 150°	Consistency 48 hrs. @ R. T.
12%	655	790
8%	550	700
4%	450	660

As the soap concentration increased the particle size of the precipitated Napalm also increased.

5. Plant Control of Sodium Soap.

In order to check an alkaline sodium soap to determine the combined - uncombined NaOH ratio, two simple titrations can be used as an excellent control.

Titration to phenolphthalein with standard acid in the presence of neutral ethyl alcohol at least equal in volume to the final volume of water present measures uncombined NaOH. Titration to methyl orange with standard acid, while holding the sodium soap near the boiling point measures both combined and uncombined NaOH. If both titrations are based on the same weight of sample, it is possible to calculate the concentration of sodium soap in the solution from the combined alkali titration and the acid value of the acid mixture used.

The ratio of combined NaOH to free NaOH is calculated as follows:

$$\frac{\text{HCl Titration of total NaOH - HCl titration of free NaOH}}{\text{HCl titration of free NaOH}} = \text{ratio}$$

Thus any change in a predetermined ratio can be checked and errors corrected at an early stage in the process.

III. Precipitation of Napalm.

1. Required Type of Agitation.

In checking the effects of agitation it was found that increasing the rate of agitation during precipitation caused a decrease in setting time. However, by raising the temperature at which the aluminum soap is precipitated the setting time may be lengthened though not nearly enough to offset the effects of rapid agitation.

The degree of agitation during the final stage of precipitation is of special importance since a great deal of aggregation occurs in a very short time at this point. If the agitation is too great, fine particles form, if too slow, large aggregates form which are difficult to disperse.

During plant operations it was found that when either two 16" two 14", or one 14" and one 16" propellers rotating at 350 R. P. M., were placed in as many as 15 different positions on a shaft mounted centrally in a 7 ft. diameter tank the percentage of particles through 40 mesh only varied from 3 to 9.

2. Degree of Washing Required.

After the precipitation of Napalm the hydrated pulp is washed to a greater or less degree to remove sodium, aluminum and/or double salts and any unreacted sodium-soap in the precipitate. It has been the experience of the Ferro group that more effective than washing to remove occluded sodium soap is the treatment with dilute aluminum sulfate after an initial separation of high salt content mother liquor.

The following data concerns Napalm precipitated using spray aluminum sulfate, the Napalm being treated as indicated after an initial separation of mother liquor:

Type Treatment	Consistency 24 hrs. @ 150°
No treatment	465
15 min., 80° F. 2% alum	585
45 min. 80° F. " "	600
2 hrs. 80° F. " "	550
2 hrs. 150° F. " "	540
4 hrs. 80° F. " "	550
6 hrs. 80° F. " "	600
20 hrs. 80° F. " "	600

There was no further washing after the alum solution was drained away.

To determine whether Napalm was harmed by the presence of substantial amounts of the salts left when Napalm was not washed extensively a regular Napalm pulp was treated as noted in Table I. It is obvious that ordinary Napalm is but slightly sensitive to the salts present when only moderate washing is practiced.

5. Factors influencing oxidation of Napalm.

It was considered the rate of oxidation of Napalm, as in many organic reactions, might be dependent on changes in the pH of the pulp, nature of the oxidation catalysts present, etc. To follow the aerial oxidation of the Napalm, iodine numbers were determined at regular intervals, the induction period being taken as the time to reach the point at which the iodine number started to drop.

Napalm of the following composition was used for the work summarized in Table II.

50% Coco Acid (whole nut grade, E. F. Drew)
25% Oleic (distilled 8 - 10° titre, Century Stearic)
25% Naphthenic (Stanco Rectified)
5.7% Al(Aluminum Sulfate, DuPont Victory Grade)

The oxidation tests were run in insulated pipes through which air at 160° F. of ambient relative humidity was passed at a linear velocity of 500 ft./min. The Napalm was dried in 3/4 inch layers in screen trays lined with cheese cloth and all Napalm was screened to pass 10 mesh. Wet Napalm (50% H_2O) was charged and observed to dry satisfactorily in the period previous to initial sampling, i. e., 24 hours. Thereafter the material was well mixed at each sampling.

The conclusions which can be drawn from the data presented in Table II follow:

a. The oxidation apparatus gives reproducible results as indicated by the good checks on the induction periods of Batches Nos. 265 and 266.

b. The length of the induction period of Napalm appears to be a function of the pH of the wet pulp. Thus, slightly acidic pulp from No. 501 had an induction period about 50% longer than the same pulp which was slightly alkaline.

c. The rate of oxidation of Napalm changes vary markedly with changes in temperature. Thus, a rise in temperature

from 160 to 195° F. reduces the induction period to 21 - 23% of that found at the lower temperature.

d. The use of antioxidants, so long as they do not function as peptizing agents in the concentrations used, appear to improve oxidation resistance markedly. U. O. P. #5 is useful, Alphanil assists considerably, while α - naphthol is tremendously potent in preventing oxidation.

e. Any evaluation of the effectiveness of antioxidants should be so conducted that the air streams passing over various samples do not mix. It appears steam distillation during the initial drying stage can vaporize antioxidant from one sample onto another and so modify the oxidation of other samples.

f. Iron in a form soluble in Napalm, as for example, an iron soap, is very active as an oxidation catalyst whereas an insoluble form such as the oxide is relatively inert. From a production angle this means that iron can be tolerated to some degree in the fatty acids used to form the alkaline sodium soaps but is very deleterious if present in the aluminum sulfate.

The table below summarizes the data on Napalm prepared using virtually the same formula as given above. Though very substantial quantities of oxidation catalysts are present, the gels prepared from the soap are quite satisfactory thus confirming the expectation that soaps very susceptible to oxidation can be satisfactory until their induction period is exceeded. The Napalm prepared from alum containing iron salts oxidized extensively on storage.

Sample	1	2	3	4
Alum Conc.	20	20	20	20
Soap Conc.	6	8	8	8
Precip. Temp.°F.	90	90	90	90
Set Time, min.	5.0	5.0	5.5	9.0
Consistency 48 hrs.@ R.T.	765	560	685	910
Consistency 7 days @ R.T.	715	610	660	
Consisteney 24 hrs.@ 150°	675	560	705	
% Metal Added	0.05% Cu	0.10% Cu	0.20% Fe	0.20% Fe
How Added	To Alum	To Alum	To Soap	To Alum

IV. Drying of the Napalm.

1. Proper Oven Conditions.

Initial work on drying indicated that Napalm could be dried in 15 to 20 hours at 160° F. when the moisture content of the pulp was between 50% and 55% and the cake depth 1-1/2 inches.

The effects of initial moisture content, cake depth, and air velocity are shown in the following table.

No. Sample	Drying Time Hrs.	Air Velocity ft/min.	Cake Depth	% Free H_2O @ Start	% on 6 mesh
1	16.5	325	1.5"	56	Ca 10
2	16.5	325	1.5"	51	10
3	16.5	325	1.5"	59	10
4	16.5	325	1.5"	57	10
5	21.0	325	2.0"	49	10
6	23.0	325	2.0"	47	35 Ca.
7	19.0	215	1.5"	56	10 Ca.

All samples dried @ 160° in cloth bottom tray.

From this data it appears that high air velocities are unnecessary, since a 50% increase gave a decrease in drying time of only 13%.

V. Packaging of the Napalm.

1. Moisture Sorption.

So that a better idea might be obtained of the difficulties to be met in the plant keeping the moisture content of the Napalm below 0.8% the following moisture sorption data was obtained.

R. H. = 50% Temp. = 80° F.

Period of Exposure	Porous Napalm 1/8" Layer	Porous Napalm 1" Layer	Vitreous Napalm 1/8" Layer
5 min	.28%	.11%	.21%
15 min	.51%	.26%	.43%
30 min.	.62%	.35%	.65%
35 min.	.66%	.38%	.69%

This extreme hygroscopicity makes operations especially difficult in humid weather.

VI. Application of Napalm Gel.

1. Combustion of Gel.

In an effort to improve the combustability of Napalm Gel, other materials were incorporated with the gels and flame temperatures determined by use of the optical pyrometer. Conditions for all tests were kept constant, and triplicates of each series were run with the results as shown below:-

Material	Average Flame Temperature ° F.	Average Burning Time in seconds.
Unthickened Gasoline	2026	105
Gel + 1/2% Mg.	2026	112
Gel + 1% Mg.	2040	116
Gel + 2% Mg.	2040	136
Gel + 2% Thermit	2030	102
Gel + 1% Mg. 1% Thermit	2026	114
Gel + 2% B Powder	2026	116
Straight 8% Gel	2026	112

In each case the gasoline in the Napalm gel burned almost completely before any combustion of metal occurred. A determination of the temperature of the gel indicated it remained close to room temperature until virtually all the solvent was evaporated because of the cooling effect of the evaporation. Combustion of metal was almost nil because of the low temperature in the gel and the sealing effect of the soap.

VII. Unmodified Naphthenates as Napalm Substitutes.

Early in the research on the Napalm type of soaps it became apparent that sorption of moisture and the oxidation of the acid radicals were two factors which markedly affected the characteristics of the soaps. Because commercial naphthenic acid contains only small amounts of readily oxidizable unsaturated compounds and substantial amounts of natural antioxidants, unmodified aluminum naphthenate might be expected to show considerably greater resistance to aerial oxidation than Napalm containing no added antioxidants.

The relative merits of the two kinds of soap, now that an antioxidant has been included in regular Napalm, is not known.

To secure a better idea of the advantages of the unmodified naphthenates as compared to Napalm, some of the factors involved in producing the former were investigated. The results of this work is reported below.

Raw Materials. Unless otherwise noted the raw materials used met these specifications:

1) Naphthenic Acid 244 A. V.
   Supplier - Std. of Cal.
   Acid Value - 246
   Sap. Value - 249
   Iodine Value - 9.5
   Color - Lark amber
   % Fe - 0.02

2) Naphthenic Acid 261 A.V. - Stanco Rectified.
   Supplier - Stanco Distributors
   Acid Value - 259
   Sap. Value - 263
   Iodine Value - 8.9
   Color - Pale Yellow
   % Fe - 0.002

5) Aluminum Sulfate
Supplier - General Chemical
Fe - 0.015
Mn - 0.004

4) Caustic Soda
Supplier - Michigan Alkali

1) Preparation of Soaps of Variable Basicities.

A series of aluminum naphthenates were prepared in which the free caustic content of the soaps was gradually increased. The data on these batches are summarized in Table III. It is believed the difficulties met in the plant when handling an aluminum naphthenate prepared from a soda soap less basic than about 300 g NaOH/1000 g acid would make such a product undesirable.

Both the naphthenic acids produced soaps which were satisfactory when the basicity was high enough. There was little apparent difference in their resistance to sintering during drying.

2) Variation of Concentrations.

Data in Table IV pertains to soaps prepared by varying the concentration of reactants, the temperature of precipitation, and in one case, the time of addition. The conclusions reached follow:

a) The aluminum sulfate solution concentration is best maintained at 30 - 44% to secure a satisfactory particle size.

b) A 15% sodium soap seems preferable to lower concentrations if very fine particles are to be avoided.

c) The precipitation temperature must not be too low if fine particles are to be avoided.

3) Coating Agents.

Hydrated aluminum naphthenate which exhibited some tendency to fuse during the drying process was coated with 5% a) starch and b) 325 M talc. Starch made the sticking during drying more severe and talc helped only a small amount.

4) From the experience gained in preparing the other naphthenates, standard precipitation conditions were established and three batches of 310, 412 and 516 g NaOH per 1000 g acid were prepared from each naphthenic acid. These batches were carefully dried, screened to

pass 6 M, redried and bottled. These soaps were used for further testing and the consistencies of their 8% gels when dispersed in S. O. L. test gasoline are tabulated in Table V.

5) Moisture Sorption. It was considered of interest to note whether the unmodified naphthenates sorbed moisture as rapidly and to the same degree as ordinary Napalm. The moisture absorption rates noted in Table VI were determined using 3/8" layers of material exposed under static conditions at 80° F. 85% R. H.

6) General Characteristics. Characteristics of the unmodified naphthenates which have been investigated only briefly are as follows:

a) Burning Rates. Eight percent Napalm and straight aluminum naphthenate gels were burned and the burning rates found to be comparable.

b) Extensibility. The extensibility of the aluminum naphthenate gels appears comparable to that of Napalm.

c) Cohesion. Cohesion in small size containers offers no great difficulties though it might cause trouble with large packages. A coating agent for the dried naphthenate would probably help considerably.

d) Oxidation. The induction periods of all of the unmodified aluminum naphthenates were not determined because of lack of time but there would seem to be little reason to suspect susceptibility to oxidation.

7) Research on the solvation rates of certain aluminum naphthenates (210 g Al/OH/1000 g [illegible] A.V.) indicated that the set and solvation time in S. O. L. gasoline was relatively insensitive to temperature over the range 75° F. to 90° F. though the magnitude of the set and solvation times was rather large. To check the characteristics at very low temperatures the naphthenate mentioned above was screened to pass 30 mesh and added to gasoline at - 10° F. Apparently there is an abrupt change in solvation rate for the soap had swelled to only half the total volume in 1 - 5 hours. Figures 1 and 2 illustrate the change in set and solvation time and the spread between the two for the most satisfactory aluminum naphthenates.

SUMMARY:

Though additional work is yet to be done on the unmodified aluminum naphthenates, research has progressed far enough to indicate soaps of adequate physical characteristics and satisfactory gasoline gelling ability can be prepared in the laboratory. Furthermore, the characteristics of the soaps are so close to those of the Napalm type there should be no unusual production problems.

Sintering of particles during the drying process might introduce more grinding difficulties than are met producing Napalm, but close control during precipitation will minimize such troubles.

The naphthenates prepared at Ferro have shown no unusual gelling properties but when properly formulated appeared as satisfactory as Napalm. Thus, though the oxidation resistance of the two types of soaps have not been compared extensively, it would seem the greatest advantage of the unmodified naphthenates lay in their oxidation resistant structure.

Author _____
S. B. Elliott

Supervisor _____
C. H. McIntyre

TABLE I.

Effect of Salts on Napalm Gel Strengths.

Plant Batch #452 - All samples dried at same humidity, and Temperature.

Treatment	% Al	% H_2O	% SO_4	% Na	2 hr. @ 150°	24 hr. @ 150°	48 hr. @ 77°	Temp. Spread.
Plant Batch Regular Treatment	5.61	.33	2.85	.67	810	844	846	36
Plant Batch Washed for 30 min. in running water	5.52	.38	1.22	.26	819	785	841	56
Plant Batch Washed 30 min. Soaked 30 min. in 20% Na_2SO_4 Solution	4.85	.35	9.41	3.9	757	770	744	36
Plant Batch Washed 30 min. Soaked 30 min. in a solution containing 10% Na_2SO_4 + 10% Alum	5.37	.68	10.02	2.4	740	672	698	68

TABLE II

Induction Periods of Napalms Processed in Various Ways.

(Heavy horizontal lines indicate grouping of samples in oxidation oven.)

Plant Batch No.	Dryer Position	Treatment	% Fe	% Mn.	Induction Period in Hours @ 160°F.	Induction Period in Hours @ 195° F.	Naphthenic Acid Used.
265	1	No. Special Treat.	.012	< .004	65	—	Stanco Sect. 227 A.V.
266	2	" " "	"	"	58	—	" "
263	3	" " "	"	"	55	—	" "
265	4	" " "	"	"	63	—	" "
301	1	Washed well - 15 min.	.018	<.004	60	14	" "
301	2	1.5 Kg. Napalm pulp 4.0 Kg H_2O 4.0 g. NaOH	"	"	42	9	" "
301	3	1.5 Kg Napalm pulp 3.0 Kg. H_2O 10 g. Alum	"	"	66	14	" "
301	4	1.5 Kg Napalm pulp 0.5 g D.O. P. #5 2.0 Kg H_2O	"	"	84	14	" "
336	1	No Special Treat.	.012	< .004	52	—	" "
336	2	Running Water - 30 min.	"	"	42	—	" "
336	3	1.5 Kg. Napalm pulp 1.5 Kg. 20% Al Sulf. 1.3 Kg H_2O	"	"	57	—	" "
Lab.	4	5% #10 motor oil Co ppt.	"	"	56	—	" "
403	1	No special treat.	.022	<.004	—	62	Oronite 244 A.V.
404	2	0.1% Alphanil Plant Material	"	"	—	72	" "
404	3	0.1% Alphanil Plant Material	"	"	—	8	" "

Table II.

Induction Periods of Napalms Processed in Various Keys.

(Heavy Horizontal lines indicate grouping of samples in oxidation oven.)

Plant batch No.	Dryer Position	Treatment	% Fe	% Mn.	Induction Period in Hrs. @ 160° F.	Induction Period in Hrs. @ 195° F.	Naphthenic Acid Used
405	4	No special treat.	.022	< .004	--	24	Oronite 244 A. V.
Lab.	1	0.05% Fe added to Alum. Sulfate	.056	< .004	48	--	" "
Lab.	2	0.01% Fe added to Alum. Sulfate	.030	< .004	86	--	" "
Lab.	3	0.05% Fe added to Sodium Soap	.068	< .004	122	--	" "
Lab.	4	0.01% Fe added to Sodium Soap	.038	< .004	118	--	" "

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Table III

Characteristics of Aluminum Naphthenates of Various Compositions.

G NaOH/ 1000 g Acid	Precip. Temp. ° F.	Soda Soap Conc. %	Naph. Acid. A.V.	Alum. Sulf. Conc. %	Time to Precip. Min.	Precip. Charac-teris tics.	Drying Characteristics.	Consistency 2 hr.	Consistency 24 hr.	Consistency 48 hr.	% H_2O	% Al	% Na	Total SO_4 %	% SO_4 not combined with Na.
165	72	15	246	44	20	Very Sticky	-----							1.33	2.18
206	72	15	246	44	20	Sticky	Completely sintered.		616	578	0.53	5.55	0.64	3.51	2.18
248	73	15	246	44	20	Sticky	Sintered badly.	783	725	757	0.40	5.87	1.12	6.39	4.04
289	75	15	246	44	20	Slightly sticky.	Sintered badly.	770	805	826	0.75	6.34	1.09	6.45	4.14
330	75	15	246	44	20	Fair part. size. Little stickiness	Sintered but could be broken easily.	794	816	795	0.90	6.71	1.29	9.32	6.62
412	86	15	246	44	20	Good part. size. Part soft.	Could be broken with difficulty.								
516	96	15	246	44	20	Part. soft, mushy, hard to filter	Could be broken with difficulty.								
206	72	15	259	44	20	Sticky			900	900		5.54			
248	72	15	259	44	20	Sticky			864	715		6.01			
289	75	15	259	44	20	Slightly sticky.			836	950		6.43			
330	75	15	259	44	20	Little stickiness			785	950		6.82			

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Table IV.

Effect of Precipitation Conditions on Aluminum Naphthenates.

G. NaOH/ 1000 g Acid	Precip. Temp. ° F.	Soda Soap Conc. %	Naph Acid. A. V.	Alum Sulf. Conc. %	Time to Precip. Min.	Precipitation Characteristics.	Drying Characteristics
310	74	15	246	20	44	Very soft and mushy	----
310	80	15	246	20	45	Very soft and mushy	----
310	93	15	246	20	15	Very fine unsatisfactory particle.	-----
310	93	15	246	30	30	Particle size good.	Sintered badly broke up easily.
310	78	9	246	44	20	Very fine unsatisfactory particle.	Dried to a hard, brittle mass.
412	86	15	246	44	20	Good part-size Part-soft.	Could be broken with difficulty.
412	90	15	246	44	20	Part size. Slightly better than 86°.	Could be broken with difficulty.
516	90	15	246	44	20	Part. Soft, hard to filter.	Could be broken with great difficulty.
516	120	15	246	44	20	Part. fine but filtered easily.	Could be broken with great difficulty.

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Table V.

Characteristics of Aluminum Naphthenate Gels.

G NaOH/ 1000 g Acid	Naph. Acid.	Consistency 2 hr.	Consistency 24 hr.	Consistency 48 hr.	% H_2O	Extens.	Solv.	Set	Set Solv.	% Al	Alum. Conc. %	Soap. Conc. %	Precip. Temp. ° F.	% Soluble Salts *
310	246	656	688	679	0.55	Good	8	15	7	8.33	44	15	60	8.51
412	246	490	605	665	0.55	Good	13	20	7	7.85	44	15	90	7.37
516	246	544	567	675	0.65	O.K.	22	32	10	8.69	44	15	120	8.19
310	259	572	550	720	0.60	Good	14	28	14	8.73	44	15	60	8.89
412	259	432	480	512	0.67	Good (weak)	20	35	15	8.10	44	15	90	8.85
516	259	385	382	537	0.80	Low Visc.	36	79	41	9.16	44	15	120	9.50

* Soluble salts were determined by ashing the soap, weighing, washing, igniting, and reweighing. Loss in weight was designated as soluble salts.

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Table VI.

Moisture Sorption - Unmodified Aluminum Naphthenates.

G NaOH/ 1000 g Acid	% H_2O Sorbed- % Weight Gain					
	0.5 hrs.	1.0 hrs.	1.5 hrs.	2.0 hrs.	15.0 hrs.	Neph A. V.
310	0.143	0.052	0.048	0.044	.244	259
412	0.177	0. 076	0.066	0.057	.274	259
516	0.178	0.084	0.067	0.070	.574	259
310	0.078	0.043	0.033	0.041	.257	246
412	0.095	0.047	0.043	0.053	.328	24[illegible]
516	0.138	0.074	0.067	0.080	.376	246

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Fig. 1

Solvation, Set, and Set-Solvation Time for Aluminum Naphthenates

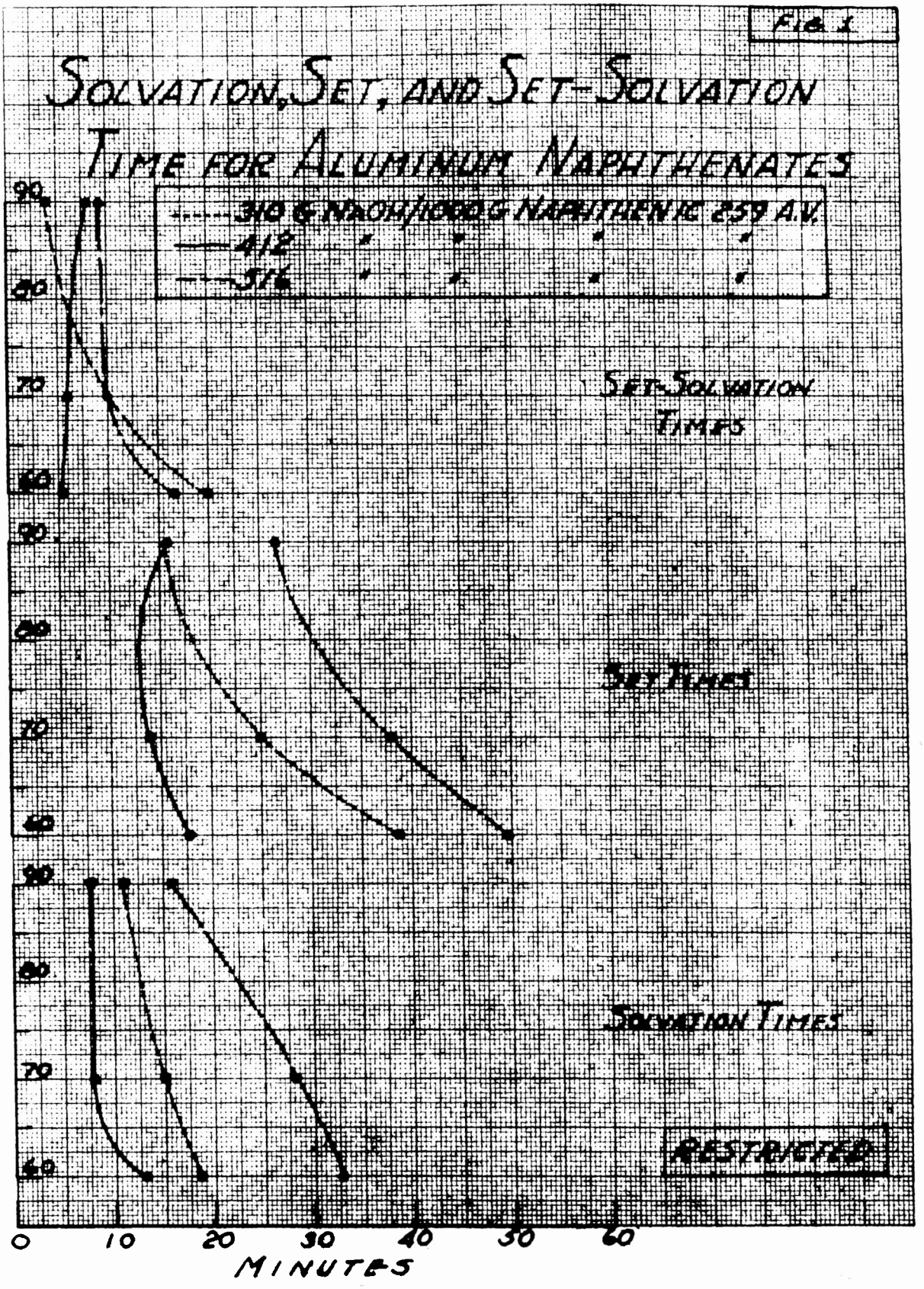
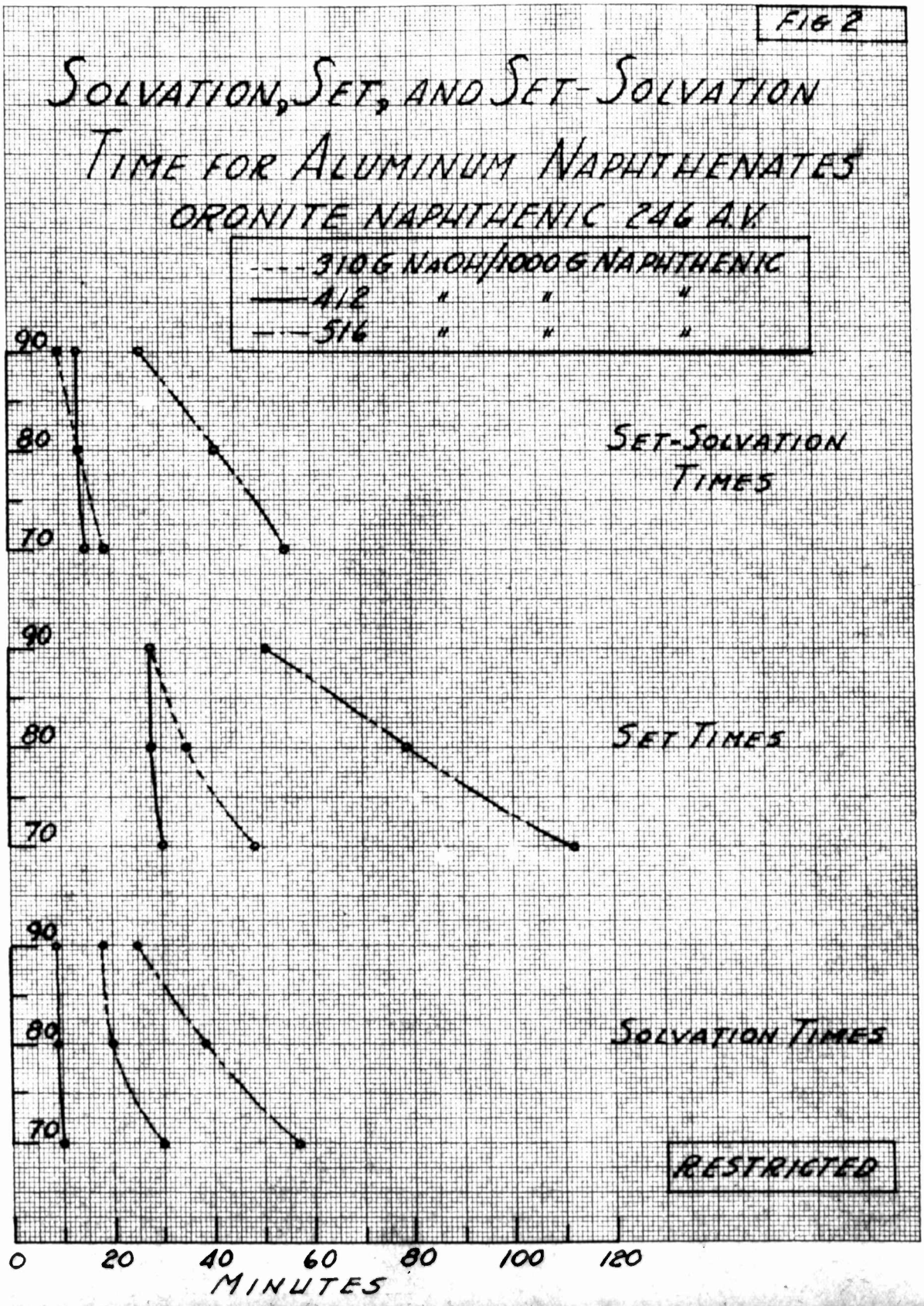


FIG 2

SOLVATION, SET, AND SET-SOLVATION TIME FOR ALUMINUM NAPHTHENATES ORONITE NAPHTHENIC 246 A.V.



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TITLE: Aluminum Soaps for Thickening Gasoline

OVER U

AUTHOR(S): McIntyre, G. H.; Elliott, S. B.
ORIGINATING AGENCY: Ferro Drier and Chemical Co.
PUBLISHED BY: Office of Scientific Research and Development, NDRC, Div 11

ATI- 31511
REVISION (None)
ORIG. AGENCY NO. (None)
PUBLISHING AGENCY NO. OSRD-3772

DATE	DOC. CLASS.	COUNTRY	LANGUAGE	PAGES	ILLUSTRATIONS
June '44	Restr.	U.S.	Eng.	22	tables, graphs

ABSTRACT:

A broad survey is presented of all the variables involved in the manufacture of Napalm thickening agent, including control of raw materials, the precipitation process, drying and packaging. It was found that, in the manufacture of Napalm, it is desirable to keep iron and manganese sulfate at very low concentrations in aluminum. The use of sodium ferrocyanide to fix the iron in a Napalm insoluble complex is of great assistance if high purity aluminum sulfate cannot be procured. A 12% sodium soap is considered the most desirable for the precipitation of Napalm.

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DIVISION: ~~Ordnance and Armament (22)~~ 5-7
SECTION: ~~Chemicals and Incendiaries (11)~~ 3

SUBJECT HEADINGS: Fuels, Fortified - Incendiary applications (42636)

ATI SHEET NO.: R-22-11-7

CLASSIFICATION CANCELLED
By authority OSRD List #3,
Dated 2-11 January 1946
By Nick Logan , USCO

18 DEC 1950 P 19/1/1

(23)

* Incendiary Mixtures
Napalm Bombs
Fuel thickeners